



Intel® Pentium® M Processor on 90 nm Process with 2-MB L2 Cache

Specification Update

January 2006

Notice: The Intel® Pentium® M processor may contain design defects or errors known as errata which may cause the product to deviate from published specifications. Current characterized errata are documented in this Specification Update.

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The Intel® Pentium® M processor may contain design defects or errors known as errata which may cause the product to deviate from published specifications. Current characterized errata are available on request.

[†]Hyper-Threading Technology requires a computer system with a Mobile Intel Pentium 4 Processor, a chipset and BIOS that utilize this technology, and an operating system that includes optimizations for this technology. Performance will vary depending on the specific hardware and software you use. See <http://www.intel.com/info/hyperthreading> for information.

Contact your local Intel sales office or your distributor to obtain the latest specifications and before placing your product order.

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Revision History

| Revision | Description | Date |
|----------|---|---------------|
| -001 | <ul style="list-style-type: none"> Initial Release | May 2004 |
| -002 | <ul style="list-style-type: none"> Updated Processor Identification Table | June 2004 |
| -003 | <ul style="list-style-type: none"> Updated Processor Identification Table Added Erratum X10 | July 2004 |
| -004 | <ul style="list-style-type: none"> Added Erratum X11, X12 and X13 | October 2004 |
| -005 | <ul style="list-style-type: none"> Added Erratum X14, X15 and X16 | November 2004 |
| -006 | <ul style="list-style-type: none"> Added Erratum X17 and X18 | December 2004 |
| -007 | <ul style="list-style-type: none"> Updated Processor Identification Table: Added C-0 S-Specs Updated Summary Tables of Changes Added Erratum X19 – X21 | February 2005 |
| -008 | <ul style="list-style-type: none"> Updated Summary of Tables of Changes Updated Processor Identification Table Added Specification Clarification X1 | April 2005 |
| -009 | <ul style="list-style-type: none"> Updated Processor Identification Table: Shading corrected from revision -008. | April 2005 |
| -010 | <ul style="list-style-type: none"> Added Erratum X22 Added Specification Clarification X2 | May 2005 |
| -011 | <ul style="list-style-type: none"> Updated Summary Tables of Changes Added Erratum X23, X24 and X25 | June 2005 |
| -012 | <ul style="list-style-type: none"> Updated Processor Identification Table 1 | July 2005 |
| -013 | <ul style="list-style-type: none"> Updated Affected and Related Documents Tables Updated Processor Identification Table 1 Removed Erratum X13 (which was duplicate of X1) | July 2005 |
| -014 | <ul style="list-style-type: none"> Added Specification Change X1 | October 2005 |
| -015 | <ul style="list-style-type: none"> Added Erratum X26 | November 2005 |
| -016 | <ul style="list-style-type: none"> Added Erratum X27 and X28 | December 2005 |
| -017 | <ul style="list-style-type: none"> Added Erratum X29 - X35 Removed Specification Clarification X1; refer to Section 18.8 of the <i>IA-32 Intel® Architecture Software Developer's Manual, Volume 3B</i> for detailed Time Stamp Counter information | January 2006 |



Preface

This document is an update to the specifications contained in the documents listed in the following Affected Related Documents table. It is a compilation of device and document errata and specification clarifications and changes, and is intended for hardware system manufacturers and for software developers of applications, operating system, and tools.

Information types defined in the Nomenclature section of this document are consolidated into this update document and are no longer published in other documents. This document may also contain information that has not been previously published.

Affected Documents

| Document Title | Document Number |
|--|----------------------------|
| <i>The Intel® Pentium® M Processor on 90 nm Process with 2-MB L2 Cache Datasheet</i> | 302189-007 |
| <i>The Intel® Pentium® M Processor with 2-MB L2 Cache and 533-MHz Front Side Bus Datasheet</i> | 305262-002 |

Related Documents

| Document Title | Document Number |
|---|------------------------|
| <i>IA-32 Intel® Architecture Software Developer's Manual, Volume 1: Basic Architecture</i> | 253665 |
| <i>IA-32 Intel® Architecture Software Developer's Manual, Volume 2A: Instruction Set Reference, A-M</i> | 253666 |
| <i>IA-32 Intel® Architecture Software Developer's Manual, Volume 2B: Instruction Set Reference, N-Z</i> | 253667 |
| <i>IA-32 Intel® Architecture Software Developer's Manual, Volume 3: System Programming Guide</i> | 253668 |
| <i>IA-32 Intel® Architecture Software Developer's Manual, Volume 3: System Programming Guide</i> | 253669 |
| <i>IA-32 Intel® Architecture Optimization Reference Manual</i> | 248966 |

Nomenclature

S-Spec Number is a five-digit code used to identify products. Products are differentiated by their unique characteristics, e.g., core speed, L2 cache size, package type, etc. as described in the processor identification information table. Care should be taken to read all notes associated with each S-Spec number.

Errata are design defects or errors. Errata may cause the behavior of the Intel® Pentium® M processor on 90 nm process with 2-MB L2 cache, to deviate from published specifications. Hardware and software, designed to be used with any given processor, must assume that all errata documented for that processor are present on all devices unless otherwise noted.

Documentation Changes include typos, errors, or omissions from the current published specifications. These changes will be incorporated in the next release of the specifications.

Specification Clarifications describe a specification in greater detail or further highlight a specification's impact to a complex design situation. These clarifications will be incorporated in the next release of the specifications.

Specification Changes are modifications to the current published specifications for the Pentium M processor. These changes will be incorporated in the next release of the specifications.



Summary Tables of Changes

The following table indicates the Specification Changes, Errata, Specification Clarifications or Documentation Changes, which apply to the listed MCH steppings. Intel intends to fix some of the errata in a future stepping of the component, and to account for the other outstanding issues through documentation or Specification Changes as noted. This table uses the following notations:

Codes Used in Summary Table

Stepping

X: Erratum, Specification Change or Clarification that applies to this stepping.

(No mark) or (Blank Box): This erratum is fixed in listed stepping or specification change does not apply to listed stepping.

Status

Doc: Document change or update that will be implemented.

PlanFix: This erratum may be fixed in a future stepping of the product.

Fixed: This erratum has been previously fixed.

NoFix: There are no plans to fix this erratum.

Row

| | |
|---------|--|
| Shaded: | This item is either new or modified from the previous version of the document. |
|---------|--|

Each specification update item is prefixed with a capital letter to distinguish the product. The key below details the letters that are used in Intel's microprocessor Specification Updates:

A = Intel® Pentium® II processor

B = Mobile Intel® Pentium® II processor

C = Intel® Celeron® processor

D = Intel® Pentium® II Xeon® processor

E = Intel® Pentium® III processor

F = Intel® Pentium® processor Extreme Edition and Intel® Pentium® D processor

G = Intel® Pentium® III Xeon® processor

H = Mobile Intel® Celeron® processor at 466 MHz, 433 MHz, 400 MHz, 366 MHz, 333 MHz, 300 MHz, and 266 MHz

J = 64-bit Intel® Xeon® processor MP with 1 MB L2 cache

K = Mobile Intel® Pentium® III Processor – M

L = Intel® Celeron® D processor

M = Mobile Intel® Celeron® processor

N = Intel® Pentium® 4 processor

O = Intel® Xeon® processor MP

P = Intel® Xeon® processor

Q = Mobile Intel® Pentium® 4 processor supporting Hyper-Threading Technology[†] on 90 nm technology process

R = Intel® Pentium® 4 processor on 90 nm process

S = 64-bit Intel® Xeon® processor with 800 MHz system bus (1 MB and 2 MB L2 cache versions)

T = Mobile Intel® Pentium® 4 processor – M

U = 64-bit Intel® Xeon® processor MP with up to 8 MB L3 Cache

V = Mobile Intel® Celeron® processor on .13 Micron process in Micro-FCPGA Package

W = Intel® Celeron® M processor

X = Intel® Pentium® M processor on 90 nm process with 2-MB L2 Cache

Y = Intel® Pentium® M processor

Z = Mobile Intel® Pentium® 4 Processor with 533 MHz System Bus

Note: The specification updates for the Pentium processor, Pentium Pro processor, and other Intel products do not use this convention.

| NO. | B1 | C0 | Plans | ERRATA |
|-----|----|----|---------|--|
| X1 | X | X | No Fix | Code Segment (CS) Is Wrong on SMM Handler when SMBASE Is Not Aligned |
| X2 | X | X | No Fix | IFU/BSU Deadlock May Cause System Hang |
| X3 | X | X | No Fix | Memory Aliasing with Inconsistent A and D Bits May Cause Processor Deadlock |
| X4 | X | X | No Fix | RDMSR or WRMSR to Invalid MSR Address May Not Cause GP Fault |
| X5 | X | X | No Fix | Unable To Disable Reads/Writes to Performance Monitoring Related MSRs |
| X6 | X | X | No Fix | Move to Control Register Instruction May Generate a Breakpoint Report |
| X7 | X | X | No Fix | Error in Instruction Fetch Unit (IFU) Can Result in an Erroneous Machine Check-Exception (#MC) |
| X8 | X | X | No Fix | Code Fetch Matching Disabled Debug Register May Cause Debug Exception |
| X9 | X | X | No Fix | Upper Four PAT Entries Not Usable with Mode B or Mode C Paging |
| X10 | X | X | No Fix | SSE/SSE2 Streaming Store Resulting in a Self-Modifying Code (SMC) Event May Cause Unexpected Behavior |
| X11 | X | X | No Fix | Code Segment Limit Violation May Occur on 4 Gigabyte Limit Check |
| X12 | X | X | No Fix | FST Instruction with Numeric and Null Segment Exceptions may cause General Protection Faults to be Missed and FP Linear Address (FLA) Mismatch |
| X13 | | | | Removed, see Erratum X1. |
| X14 | X | X | No Fix | Page with PAT (Page Attribute Table) Set to USWC (Uncacheable Speculative Write Combine) While Associated MTRR (Memory Type Range Register) is UC (Uncacheable) May Consolidate to UC |
| X15 | X | X | No Fix | Under Certain Conditions LTR (Load Task Register) Instruction May Result in System Hang |
| X16 | X | X | No Fix | Loading from Memory Type USWC (Uncacheable Speculative Write Combine) May Get Its Data Internally Forwarded from a Previous Pending Store |
| X17 | X | X | No Fix | FXSAVE after FNINIT without an Intervening FP (Floating Point) Instruction May Save Uninitialized Values for FDP (x87 FPU Instruction Operand (Data) Pointer Offset) and FDS (x87 FPU Instruction Operand (Data) Pointer Selector) |
| X18 | X | X | No Fix | FSTP (Floating Point Store) Instruction under Certain Conditions May Result In Erroneously Setting a Valid Bit on an FP (Floating Point) Stack Register |
| X19 | | X | No Fix | An Execute Disable Bit Violation May Occur on a Data Page-Fault |
| X20 | | X | No Fix | CPUID Leaf 0x80000006 May Provide the Incorrect Value for an 8-Way Associative Cache |
| X21 | X | | PlanFix | Snoops during the Execution of a HLT (Halt) Instruction May Lead to Unexpected System Behavior |
| X22 | X | X | No Fix | Invalid Entries in Page-Directory-Pointer-Table-Register (PDPTR) May Cause General Protection (#GP) Exception if the Reserved Bits are Set to One |
| X23 | X | X | No Fix | INIT Does Not Clear Global Entries in the TLB |

| NO. | B1 | C0 | Plans | ERRATA |
|-----|----|----|--------|--|
| X24 | X | X | No Fix | Use of Memory Aliasing with Inconsistent Memory Type May Cause System Hang |
| X25 | X | X | No Fix | Machine Check Exception May Occur When Interleaving Code between Different Memory Types |
| X26 | X | X | No Fix | Split I/O Writes Adjacent to Retry of APIC End of Interrupt (EOI) Request May Cause Livelock Condition |
| X27 | X | X | No Fix | General Protection (#GP) Fault May Not Be Signaled On Data Segment Limit Violation above 4G Limit |
| X28 | X | X | No Fix | DR3 Address Match on MOVD/MOVQ/MOVBQ Memory Store Instruction May Incorrectly Increment Performance Monitoring Count for Saturating SIMD Instructions Executed (Event B1h) |
| X29 | X | X | No Fix | Pending x87 FPU Exceptions (#MF) Following STI May Be Serviced before Higher Priority Interrupts |
| X30 | X | X | No Fix | Processor INIT# Will Cause a System Hang If Triggered during an NMI Interrupt Routine Performed during Shutdown |
| X31 | X | X | No Fix | Certain Performance Monitoring Counters Related to Bus, L2 Cache and Power Management Are Inaccurate |
| X32 | X | X | No Fix | CS Limit Violation on RSM May Be Serviced before Higher Priority Interrupts/Exceptions |
| X33 | X | X | No Fix | A Write to an APIC Register Sometimes May Appear to Have Not Occurred |
| X34 | X | X | No Fix | The Processor May Report a #TS Instead of a #GP Fault |
| X35 | X | X | No Fix | BTS Message May Be Lost When the STPCLK# Signal Is Active |

| NO. | SPECIFICATION CLARIFICATION |
|-----|--|
| X1 | Specification Clarification with Respect to Time-stamp Counter – Removed |
| X2 | Thermal Diode Offset Specification Clarification |

| Number | SPECIFICATION CHANGES |
|--------|---|
| X1 | AGTL+ Buffer On Resistance (Ron) Specification Correction |

| NO. | B1 | C0 | Plans | DOCUMENTATION CHANGES |
|-----|----|----|-------|---|
| | | | | There are no Documentation Changes in this Specification Update revision. |

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Identification Information

The Intel Pentium M processor on 90 nm process with 2-MB L2 cache can be identified by the following values:

| Family ¹ | Model ² | Brand ID ³ |
|---------------------|--------------------|-----------------------|
| 0110 | 1101 | 00010110 |

NOTES:

1. The Family corresponds to bits [11:8] of the EDX register after Reset, bits [11:8] of the EAX register after the CPUID instruction is executed with a 1 in the EAX register.
2. The Model corresponds to bits [7:4] of the EDX register after Reset, bits [7:4] of the EAX register after the CPUID instruction is executed with a 1 in the EAX register.
3. The Brand ID corresponds to bits [7:0] of the EBX register after the CPUID instruction is executed with a1 in the EAX register.

Table 1. Identification Table

| QDF/ S-spec | Processor Numbers | Product Stepping | FSB Frequency | CPU Signature | Core Speed | | Package Micro-FCBGA-Pb= μ-BGA Lead Free | QDF Notes |
|----------------|----------------------|---------------------|------------------|------------------|--------------------------------|----------------------------|---|--------------|
| | | | | | Highest Freq. Mode (HFM) | Lowest Freq. Mode (LFM) | | |
| SL86G | 730 | C-0 | 533 | 06D8h | 1.6 GHz | 800 MHz | Micro-FCPGA | 2,7 |
| SL7SA | 740 | C-0 | 533 | 06D8h | 1.73 GHz | 800 MHz | Micro-FCPGA | 2,7 |
| SL7S9 | 750 | C-0 | 533 | 06D8h | 1.86 GHz | 800 MHz | Micro-FCPGA | 2,7 |
| SL7SM | 760 | C-0 | 533 | 06D8h | 2.0 GHz | 800 MHz | Micro-FCPGA | 2,7 |
| SL7SL | 770 | C-0 | 533 | 06D8h | 2.13 GHz | 800 MHz | Micro-FCPGA | 2,8 |
| SL7VB | 780 | C-0 | 533 | 06D8h | 2.26 GHz | 800 MHz | Micro-FCPGA | 9,2 |
| SL86M | 730 | C-0 | 533 | 06D8h | 1.6 GHz | 800 MHz | Micro-FCBGA | 2,7 |
| SL7S8 | 740 | C-0 | 533 | 06D8h | 1.73 GHz | 800 MHz | Micro-FCBGA | 2,7 |
| SL7SR | 750 | C-0 | 533 | 06D8h | 1.86 GHz | 800 MHz | Micro-FCBGA | 2,7 |
| SL7SQ | 760 | C-0 | 533 | 06D8h | 2.0 GHz | 800 MHz | Micro-FCBGA | 2,7 |
| SL7SP | 770 | C-0 | 533 | 06D8h | 2.13 GHz | 800 MHz | Micro-FCBGA | 2,8 |
| SL7SN | 780 | C-0 | 533 | 06D8h | 2.26 GHz | 800 MHz | Micro-FCBGA | 9,2 |
| SL86B | 740 | C-0 | 533 | 06D8h | 1.73 GHz | 800 MHz | Micro-FCBGA-Pb | 2,7 |
| SL86A | 750 | C-0 | 533 | 06D8h | 1.86 GHz | 800 MHz | Micro-FCBGA-Pb | 2,7 |
| SL869 | 760 | C-0 | 533 | 06D8h | 2.0 GHz | 800 MHz | Micro-FCBGA-Pb | 2,7 |
| SL868 | 770 | C-0 | 533 | 06D8h | 2.13 GHz | 800 MHz | Micro-FCBGA-Pb | 2,8 |
| SL8QK | 780 | C-0 | 533 | 06D8h | 2.26 GHz | 800 MHz | Micro-FCBGA-Pb | 9,2 |
| SL8QF | 778 | C-0 | 400 | 06D8h | 1.6 GHz | 600 MHz | Micro-FCBGA | 2,3 |
| SL89X | 758 | C-0 | 400 | 06D8h | 1.5 GHz | 600 MHz | Micro-FCBGA | 2,3 |
| SL8A3 | 723 | C-0 | 400 | 06D8h | 1.0 GHz | 600 MHz | Micro-FCBGA | 4,5 |
| SL8LM | 733J | C-0 | 400 | 06D8h | 1.1 GHz | 600 MHz | Micro-FCBGA | 4,10 |

| QDF/ S-spec | Processor Numbers | Product Stepping | FSB Frequency | CPU Signature | Core Speed | | Package Micro-FCBGA-Pb= μ-BGA Lead Free | QDF Notes |
|----------------|----------------------|---------------------|------------------|------------------|--------------------------------|----------------------------|---|--------------|
| | | | | | Highest Freq. Mode (HFM) | Lowest Freq. Mode (LFM) | | |
| SL8A2 | 733J | C-0 | 400 | 06D8h | 1.1 GHz | 600 MHz | Micro-FCBGA | 4,5 |
| SL89Z | 753 | C-0 | 400 | 06D8h | 1.2 GHz | 600 MHz | Micro-FCBGA | 4,5 |
| SL8LL | 753 | C-0 | 400 | 06D8h | 1.2 GHz | 600 MHz | Micro-FCBGA | 4,10 |
| SL8QG | 778 | C-0 | 400 | 06D8h | 1.6 GHz | 600 MHz | Micro-FCBGA-Pb | 2,3 |
| SL89M | 758 | C-0 | 400 | 06D8h | 1.5 GHz | 600 MHz | Micro-FCBGA-Pb | 2,3 |
| SL89R | 723 | C-0 | 400 | 06D8h | 1.0 GHz | 600 MHz | Micro-FCBGA-Pb | 2,3 |
| SL8LT | 733J | C-0 | 400 | 06D8h | 1.1 GHz | 600 MHz | Micro-FCBGA-Pb | 4,10 |
| SL89Q | 733J | C-0 | 400 | 06D8h | 1.1 GHz | 600 MHz | Micro-FCBGA-Pb | 4,5 |
| SL89P | 753 | C-0 | 400 | 06D8h | 1.2 GHz | 600 MHz | Micro-FCBGA-Pb | 4,5 |
| SL8LS | 753 | C-0 | 400 | 06D8h | 1.2 GHz | 600 MHz | Micro-FCBGA-Pb | 4,10 |
| SL89N | 738 | C-0 | 400 | 06D8h | 1.4 GHz | 600 MHz | Micro-FCBGA-Pb | 2,3 |
| SL89Y | 738 | C-0 | 400 | 06D8h | 1.4 GHz | 600 MHz | Micro-FCPGA | 2,3 |
| SL7EM | 755 | B-1 | 400 | 06D6h | 2.0 GHz | 600 MHz | Micro-FCPGA | 1,2 |
| SL7EL | 755 | B-1 | 400 | 06D6h | 2.0 GHz | 600 MHz | Micro-FCBGA | 1,2 |
| SL7EN | 745 | B-1 | 400 | 06D6h | 1.8 GHz | 600 MHz | Micro-FCPGA | 1,2 |
| SL7EQ | 745 | B-1 | 400 | 06D6h | 1.8 GHz | 600 MHz | Micro-FCBGA | 1,2 |
| SL7EP | 735 | B-1 | 400 | 06D6h | 1.7 GHz | 600 MHz | Micro-FCPGA | 1,2 |
| SL7ER | 735 | B-1 | 400 | 06D6h | 1.7 GHz | 600 MHz | Micro-FCBGA | 1,2 |
| SL7EG | 725 | B-1 | 400 | 06D6h | 1.6 GHz | 600 MHz | Micro-FCPGA | 1,2 |
| SL7F2 | 725 | B-1 | 400 | 06D6h | 1.6 GHz | 600 MHz | Micro-FCBGA | 1,2 |
| SL7GL | 715 | B-1 | 400 | 06D6h | 1.5 GHz | 600 MHz | Micro-FCPGA | 1,2 |
| SL7GK | 715 | B-1 | 400 | 06D6h | 1.5 GHz | 600 MHz | Micro-FCBGA | 1,2 |
| SL7F3 | 738 | B-1 | 400 | 06D6h | 1.4 GHz | 600 MHz | Micro-FCBGA | 2,3 |
| SL7F4 | 733 | B-1 | 400 | 06D6h | 1.1 GHz | 600 MHz | Micro-FCBGA | 4,5 |
| SL7VD | 733 | B-1 | 400 | 06D6h | 1.1 GHz | 600 MHz | Micro-FCBGA | 4,5 |
| SL7V2 | 723 | B-1 | 400 | 06D6h | 1.0 GHz | 600 MHz | Micro-FCBGA | 4,5 |

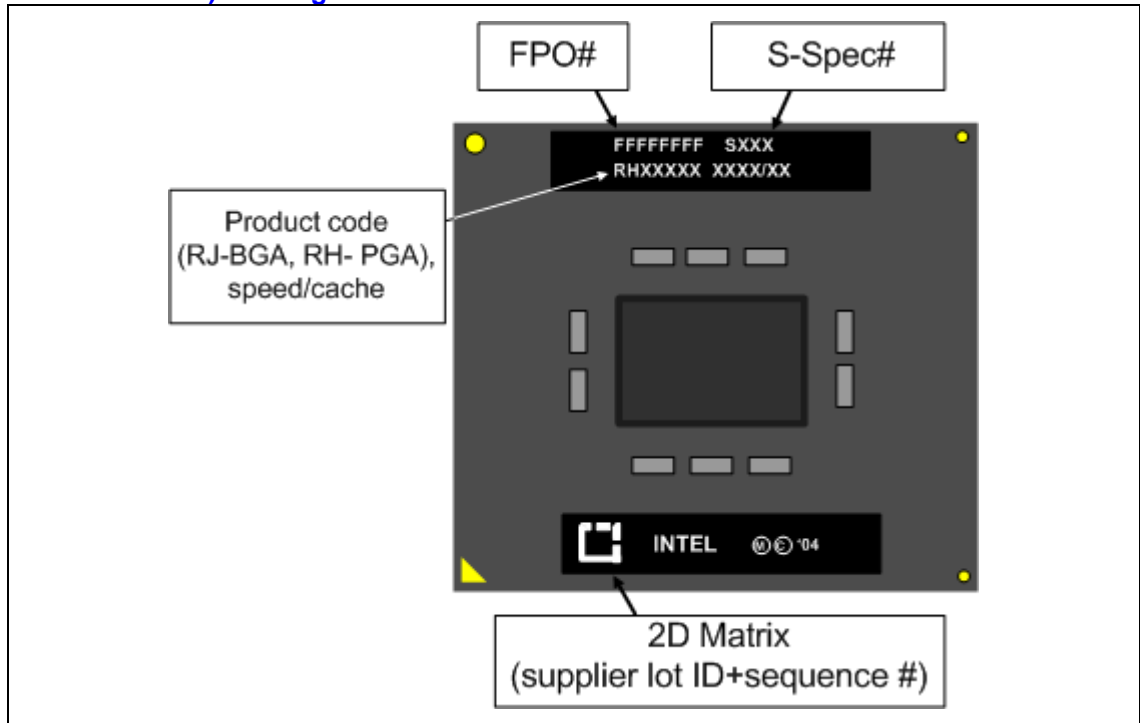
NOTES

- Multiple HFM VID's; VCC_CORE = 1.340-1.276 V for Highest Frequency Mode (HFM).
- VCC_CORE = 0.988 V for Lowest Frequency Mode (LFM).
- VCC_CORE = 1.116 V for Highest Frequency Mode (HFM).
- VCC_CORE = 0.812 V for Lowest Frequency Mode (LFM).
- VCC_CORE = 0.940 V for Highest Frequency Mode (HFM).
- Multiple HFM VID's; VCC_CORE = 1.356-1.308 V for Highest Frequency Mode (HFM).
- VCC_CORE = 1.260-1.356 V for Highest Frequency Mode (HFM).
- VCC_CORE = 1.260-1.372 V for Highest Frequency Mode (HFM).
- VCC_CORE = 1.260-1.404 V for Highest Frequency Mode (HFM).
- VCC_CORE = 0.876-0.956 V for Highest Frequency Mode (HFM).

Component Marking Information

The Intel Pentium M Processor on 90 nm process with 2-MB L2 cache may be identified by the following component markings:

Figure 1. Intel® Pentium® M Processor on 90 nm Process with 2-MB L2 Cache (Micro-FCPGA/FCBGA) Markings



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Errata

X1. Code Segment (CS) Is Wrong on SMM Handler When SMBASE Is Not Aligned

Problem: With SMBASE being relocated to a non-aligned address, during SMM entry the CS can be improperly updated, which can lead to an incorrect SMM handler.

Implication: This is a rare condition that may result in a system hang. Intel has not observed this erratum with any commercially available software or system.

Workaround: Align SMBASE to 32 kB.

Status: For the steppings affected, see the *Summary of Tables of Changes*.

X2. IFU/BSU Deadlock May Cause System Hang

Problem: A lockable instruction with memory operand that spans across two pages may, given some rare internal conditions, hang the system.

Implication: When this erratum occurs, the system may hang. Intel has not observed this erratum with any commercially available software or system.

Workaround: Lockable data should always be contained in a single page.

Status: For the steppings affected, see the *Summary of Tables of Changes*.

X3. Memory Aliasing with Inconsistent A and D Bits May Cause Processor Deadlock

Problem: In the event that software implements memory aliasing by having two page directory entries (PDEs) point to a common page table entry (PTE) and the Accessed and Dirty bits for the two PDEs are allowed to become inconsistent the processor may become deadlocked.

Implication: This erratum has not been observed with commercially available software.

Workaround: Software that needs to implement memory aliasing in this way should manage the consistency of the Accessed and Dirty bits.

Status: For the steppings affected, see the *Summary of Tables of Changes*.



X4. RDMSR or WRMSR to Invalid MSR Address May Not Cause GP Fault

Problem: The RDMSR and WRMSR instructions allow reading or writing of MSR's (Model Specific Registers) based on the index number placed in ECX. The processor should reject access to any reserved or unimplemented MSRs by generating #GP(0). However, there are some invalid MSR addresses for which the processor will not generate #GP(0). This erratum has not been observed with commercially available software.

Implication: For RDMSR, undefined values will be read into EDX:EAX. For WRMSR, undefined processor behavior may result.

Workaround: Do not use invalid MSR addresses with RDMSR or WRMSR.

Status: For the steppings affected, see the *Summary of Tables of Changes*.

X5. Unable to Disable Reads/Writes to Performance Monitoring Related MSRs

Problem: The Performance Monitoring Available bit in the miscellaneous processor features MSR (IA32_MISC_ENABLES.7) was defined so that when it is cleared to a 0, RDMSR/ WRMSR/RDPMC instructions would return all zeros for reads of and prevent any write to Performance Monitoring related MSRs. Currently it is possible to read from or write to Performance Monitoring related MSRs when the Performance Monitoring Available bit is cleared to a 0.

Implication: It is not possible to disallow reads and writes to the Performance Monitoring MSRs. Intel has not observed this erratum with commercially available software of system.

Workaround: None.

Status: For the steppings affected, see the *Summary of Tables of Changes*.

X6. Move to Control Register Instruction May Generate a Breakpoint Report

Problem: A move (MOV) to Control register (CR) instruction where Control register is CR0, CR3 or CR4 may generate a breakpoint report.

Implication: MOV to Control Register Instruction is not expected to generate a breakpoint report.

Workaround: Ignore breakpoint data from MOV to CR instruction.

Status: For the steppings affected, see the *Summary of Tables of Changes*.

X7. Error in Instruction Fetch Unit (IFU) Can Result in an Erroneous Machine Check-Exception (#MC)

Problem: A rare combination of events including the generation of a bus lock(s), the execution of a WBINVD instruction, and a page accessed or dirty bit assist may result in an erroneous Machine Check-Exception (#MC).

Implication: Due to this erratum, unexpected machine check-exception (#MC) is generated. Intel has not been able to reproduce this erratum with commercially available software.

Workaround: It is possible for BIOS to contain a workaround for this erratum.

Status: For the steppings affected, see the *Summary of Tables of Changes*.

X8. Code Fetch Matching Disabled Debug Register May Cause Debug Exception

Problem: The bits L0-3 and G0-3 enable breakpoints local to a task and global to all tasks, respectively. If one of these bits is set, a breakpoint is enabled, corresponding to the addresses in the debug registers DR0-DR3. If at least one of these breakpoints is enabled, any of these registers are disabled (i.e., Ln and Gn are 0), and RWn for the disabled register is 00 (indicating a breakpoint on instruction execution), normally an instruction fetch will not cause an instruction-breakpoint fault based on a match with the address in the disabled register(s). However, if the address in a disabled register matches the address of a code fetch which also results in a page fault, an instruction-breakpoint fault will occur.

Implication: While debugging software, extraneous instruction-breakpoint faults may be encountered if breakpoint registers are not cleared when they are disabled. Debug software which does not implement a code breakpoint handler will fail, if this occurs. If a handler is present, the fault will be serviced. Mixing data and code may exacerbate this problem by allowing disabled data breakpoint registers to break on an instruction fetch.

Workaround: The debug handler should clear breakpoint registers before they become disabled.

Status: For the steppings affected, see the *Summary of Tables of Changes*.

X9. Upper Four PAT Entries Not Usable With Mode B or Mode C Paging

Problem: The Page Attribute Table (PAT) contains eight entries, which must all be initialized and considered when setting up memory types for the Pentium M processor. However, in Mode B or Mode C paging, the upper four entries do not function correctly for 4-Kbyte pages. Specifically, bit 7 of page table entries that translate addresses to 4-Kbyte pages should be used as the upper bit of a 3-bit index to determine the PAT entry that specifies the memory type for the page. When Mode B (CR4.PSE = 1) and/or Mode C (CR4.PAE) are enabled, the processor forces this bit to zero when determining the memory type regardless of the value in the page table entry. The upper four entries of the PAT function correctly for 2-Mbyte and 4-Mbyte large pages (specified by bit 12 of the page directory entry for those translations).

Implication: Only the lower four PAT entries are useful for 4-KB translations when Mode B or C paging is used. In Mode A paging (4-Kbyte pages only), all eight entries may be used. All eight entries may be used for large pages in Mode B or C paging.

Workaround: None.

Status: For the steppings affected, see the *Summary of Tables of Changes*.



X10. SSE/SSE2 Streaming Store Resulting in a Self-Modifying Code (SMC) Event May Cause Unexpected Behavior

Problem: An SSE or SSE2 streaming store that results in a Self-Modifying Code (SMC) event may cause unexpected behavior. The SMC event occurs on a full address match of code contained in L1 cache.

Implication: Due to this erratum, any of the following events may occur:

1. A data access break point may be incorrectly reported on the instruction pointer (IP) just before the store instruction.
2. A non-cacheable store can appear twice on the external bus (the first time it will write only 8 bytes, the second time it will write the entire 16 bytes).

Intel has not observed this erratum with any commercially available software. This erratum has been seen in a synthetic test environment.

Workaround: None.

Status: For the steppings affected, see the *Summary of Tables of Changes*.

X11. Code Segment Limit Violation May Occur on 4 Gigabyte Limit Check

Problem: Code Segment limit violation may occur on 4 Gigabyte limit check when the code stream wraps around in a way that one instruction ends at the last byte of the segment and the next instruction begins at 0x0.

Implication: This is a rare condition that may result in a system hang. Intel has not observed this erratum with any commercially available software, or system.

Workaround: Avoid code that wraps around segment limit.

Status: For the steppings affected, see the *Summary of Tables of Changes*.

X12. FST Instruction with Numeric and Null Segment Exceptions May Cause General Protection Faults to Be Missed and FP Linear Address (FLA) Mismatch

Problem: FST instruction combined with numeric and null segment exceptions may cause General Protection Faults to be missed and FP Linear Address (FLA) mismatch.

Implication: This is a rare condition that may result in a system hang. Intel has not observed this erratum with any commercially available software, or system.

Workaround: None identified.

Status: For the steppings affected, see the *Summary of Tables of Changes*.

X13. **Removed; See Erratum X1.**

X14. **Page with PAT (Page Attribute Table) Set to USWC (Uncacheable Speculative Write Combine) While Associated MTRR (Memory Type Range Register) Is UC (Uncacheable) May Consolidate to UC**

Problem: A page whose PAT memory type is USWC while the relevant MTRR memory type is UC, the consolidated memory type may be treated as UC (rather than WC as specified in *IA-32 Intel® Architecture Software Developer's Manual*).

Implication: When this erratum occurs, the memory page may be as UC (rather than WC). This may have a negative performance impact.

Workaround: None identified.

Status: For the steppings affected, see the *Summary of Tables of Changes*.

X15. **Under Certain Conditions LTR (Load Task Register) Instruction May Result in System Hang**

Problem: An LTR instruction may result in a system hang if all the following conditions are met:

1. Invalid data selector of the TR (Task Register) resulting with either #GP (General Protection Fault) or #NP (Segment Not Present Fault).
2. GDT (Global Descriptor Table) is not 8-bytes aligned.
3. Data BP (breakpoint) is set on cache line containing the descriptor data.

Implication: This erratum may result in system hang if all conditions have been met. This erratum has not been observed in commercial operating systems or software. For performance reasons, GDT is typically aligned to 8-bytes.

Workaround: Software should align GDT to 8-bytes.

Status: For the steppings affected, see the *Summary of Tables of Changes*.



X16. Loading from Memory Type USWC (Uncacheable Speculative Write Combine) May Get Its Data Internally Forwarded from a Previous Pending Store

Problem: A load from memory type USWC may get its data internally forwarded from a pending store. As a result, the expected load may never be issued to the external bus.

Implication: When this erratum occurs, a USWC load request may be satisfied without being observed on the external bus. There are no known usage models where this behavior results in any negative side-effects.

Workaround: Do not use memory type USWC for memory that has read side-effects.

Status: For the steppings affected, see the Summary of Table of Change

X17. FXSAVE after FNINIT without an Intervening FP (Floating Point) Instruction May Save Uninitialized Values for FDP (x87 FPU Instruction Operand (Data) Pointer Offset) and FDS (x87 FPU Instruction Operand (Data) Pointer Selector)

Problem: An FXSAVE after FNINIT without an intervening FP instruction may save uninitialized values for FDP and FDS.

Implication: When this erratum occurs, the values for FDP/FDS in the FXSAVE structure may appear to be random values. These values will be initialized by the first FP instruction executed after the FXRSTOR that restore the saved floating point state. Any FP instruction with memory operand will initialize FDP/FDS. Intel has not observed this erratum with any commercially available software.

Workaround: After an FNINIT, do not expect the FXSAVE memory image to be correct, until at least one FP instruction with a memory operand has been executed.

Status: For the steppings affected, see the *Summary of Tables of Changes*.

X18. FSTP (Floating Point Store) Instruction Under Certain Conditions May Result In Erroneously Setting a Valid Bit on an FP (Floating Point) Stack Register

Problem: An FSTP instruction with a PDE/PTE (Page Directory Entry/Page Table Entry) A/D bit update followed by user mode access fault due to a code fetch to a page that has supervisor only access permission may result in erroneously setting a valid bit of an FP stack register. The FP top of stack pointer is unchanged.

Implication: This erratum may cause an unexpected stack overflow.

Workaround: User mode code should not count on being able to recover from illegal accesses to memory regions protected with supervisor only access when using FP instructions.

Status: For the steppings affected, see the *Summary of Tables of Changes*.

X19. An Execute Disable Bit Violation May Occur on a Data Page-Fault

Problem: Under a combination of internal events, unexpected Execute Disable violations may occur on data accesses that are Execute Disable protected.

Implication: This erratum may cause unexpected Execute Disable violations.

Workaround: It is possible for the BIOS to contain a workaround for this erratum.

Status: For the steppings affected, see the *Summary of Tables of Changes*.

X20. CPUID Leaf 0x80000006 May Provide the Incorrect Value for an 8-Way Associative Cache

Problem: CPUID leaf 0x80000006 may return 0x8 in ECX [15:12] to indicate 8-way associative cache, but the correct encoding for an 8-way associative cache is 0x6.

Implication: Software that depends on the associativity of the cache may not function correctly.

Workaround: It is possible for the BIOS to contain a workaround for this erratum.

Status: For the steppings affected, see the *Summary of Tables of Changes*.

X21. Snoops during the Execution of a HLT (Halt) Instruction May Lead to Unexpected System Behavior

Problem: If during the execution of a HLT instruction an external snoop causes an eviction from the instruction fetch unit (IFU) instruction cache, the processor may, on exit from the HLT state, erroneously read stale data from the victim cache.

Implication: This erratum may lead to unexpected system behavior. Intel has only observed this condition in non-mobile configurations.

Workaround: It is possible for the BIOS to contain a workaround for this erratum.

Status: For the steppings affected, see the *Summary of Tables of Changes*.

X22. Invalid Entries in Page-Directory-Pointer-Table-Register (PDPTR) May Cause General Protection (#GP) Exception If the Reserved Bits are Set to One

Problem: Invalid entries in Page-Directory-Pointer-Table-Register (PDPTR) that have the reserved bits set to one, may cause a General Protection (#GP) exception.

Implication: Intel has not observed this erratum with any commercially available software.

Workaround: Do not set the reserved bits to one when PDPTR entries are invalid.

Status: For the steppings affected, see the *Summary of Table of Changes*.



X23. INIT Does Not Clear Global Entries in the TLB

Problem: INIT may not flush a TLB entry when:

1. The processor is in protected mode with paging enabled and the page global enable flag is set (PGE bit of CR4 register)
2. G bit for the page table entry is set
3. TLB entry is present in TLB when INIT occurs

Implication: Software may encounter unexpected page fault or incorrect address translation due to a TLB entry erroneously left in TLB after INIT.

Workaround: Write to CR3, CR4 or CR0 registers before writing to memory early in BIOS code to clear all the global entries from TLB.

Status: For the steppings affected, see the *Summary of Tables of Changes*.

X24. Use of Memory Aliasing with Inconsistent Memory Type May Cause System Hang

Problem: Software that implements memory aliasing by having more than one linear addresses mapped to the same physical page with different cache types may cause the system to hang. This would occur if one of the addresses is non-cacheable used in code segment and the other a cacheable address. If the cacheable address finds its way in instruction cache, and non-cacheable address is fetched in IFU, the processor may invalidate the non-cacheable address from the fetch unit. Any micro-architectural event that causes instruction restart will expect this instruction to still be in fetch unit and lack of it will cause system hang.

Implication: This erratum has not been observed with commercially available software.

Workaround: Although it is possible to have a single physical page mapped by two different linear addresses with different memory types, Intel has strongly discouraged this practice as it may lead to undefined results. Software that needs to implement memory aliasing should manage the memory type consistency.

Status: For the steppings affected, see the *Summary of Tables of Changes*.

X25. Machine Check Exception May Occur When Interleaving Code between Different Memory Types

Problem: A small window of opportunity exists where code fetches interleaved between different memory types may cause a machine check exception. A complex set of micro-architectural boundary conditions is required to expose this window.

Implication: Interleaved instruction fetches between different memory types may result in a machine check exception. The system may hang if machine check exceptions are disabled. Intel has not observed the occurrence of this erratum while running commercially available applications or operating systems.

Workaround: Software can avoid this erratum by placing a serializing instruction between code fetches between different memory types.

Status: For the steppings affected, see the *Summary of Tables of Changes*.

X26. Split I/O Writes Adjacent to Retry of APIC End of Interrupt (EOI) Request May Cause Livelock Condition

Problem: When Split I/O instruction writes occur adjacent to a retry of a Local APIC End of Interrupt (EOI) request by the chipset, a livelock condition may result. The required sequences of events are:

1. The processor issues a Local APIC EOI message.
2. The chipset responds with a retry because its downstream ports are full. It expects the processor to return with the same EOI request.
3. The processor issues a Split I/O write instruction instead.
4. The chipset responds with a retry because it expected the APIC EOI.
5. The processor insists the Split I/O write instruction must be completed and issues write instruction again.

Implication: A processor livelock may occur causing a system hang. This issue has only been observed in synthetic lab testing conditions and has not been seen in any commercially available applications. The erratum does not occur with Intel mobile chipset based platforms.

Workaround: Use the PIC instead of the APIC for the interrupt controller.

Status: For the steppings affected, see the *Summary of Tables of Changes*.

X27. General Protection (#GP) Fault May Not Be Signaled on Data Segment Limit Violation above 4-G Limit

Products: Memory accesses to flat data segments (base = 00000000h) that occur above the 4-G limit (0ffffffffh) may not signal a #GP fault.

Implication: When such memory accesses occur, the system may not issue a #GP fault.

Workaround: Software should ensure that memory accesses do not occur above the 4-G limit (0xffffffffh).

Status: For the steppings affected, see the *Summary of Tables of Changes*.



X28. DR3 Address Match on MOVD/MOVQ/MOVNTQ Memory Store Instruction May Incorrectly Increment Performance Monitoring Count for Saturating SIMD Instructions Executed (Event B1h)

Problem: Performance monitoring for Event B1h normally increments on saturating SIMD instruction executed. Regardless of DR7 programming, if the linear address of a memory store MOVD/MOVQ/MOVNTQ instruction executed matches the address in DR3, the B1h counter may be incorrectly incremented.

Implication: The value observed for performance monitoring count for saturating SIMD instructions executed may be too high.

Workaround: None identified.

Status: For the steppings affected, see the *Summary of Tables of Changes*.

X29. Pending x87 FPU Exceptions (#MF) Following STI May Be Serviced before Higher Priority Interrupts

Problem: Interrupts that are pending prior to the execution of the STI (Set Interrupt Flag) instruction are serviced immediately after the STI instruction is executed. Because of this erratum, if following STI, an instruction that triggers a #MF is executed while STPCLK#, Enhanced Intel SpeedStep® Technology transitions or Thermal Monitor 1 events occur, the pending #MF may be serviced before higher priority interrupts.

Implication: Software may observe #MF being serviced before higher priority interrupts.

Workaround: None identified.

Status: For the steppings affected, see the *Summary of Tables of Changes*.

X30. Processor INIT# Will Cause a System Hang if Triggered during an NMI Interrupt Routine Performed during Shutdown

Problem: During the execution of an NMI interrupt handler, if shutdown occurs followed by the INIT# signal being triggered, the processor will attempt initialization but fail soft reset.

Implication: Due to this erratum the system may hang.

Workaround: None identified.

Status: For the steppings affected, see the *Summary of Tables of Changes*.

X31. Certain Performance Monitoring Counters Related to Bus, L2 Cache and Power Management Are Inaccurate

Problem: All Performance Monitoring Counters in the ranges 21H-3DH and 60H-7FH may have inaccurate results up to ± 7 .

Implication: There may be a small error in the affected counts.

Workaround: None identified.

Status: For the steppings affected, see the *Summary of Tables of Changes*.

X32. CS Limit Violation on RSM May Be Serviced before Higher Priority Interrupts/Exceptions

Problem: When the processor encounters a CS (Code Segment) limit violation, a #GP (General Protection Exception) fault is generated after all higher priority Interrupts and exceptions are serviced. Because of this erratum, if RSM (Resume from System Management Mode) returns to execution flow where a CS limit violation occurs, the #GP fault may be serviced before a higher priority Interrupt or Exception (e.g. NMI (Non-Maskable Interrupt), Debug break(#DB), Machine Check (#MC), etc.).

Implication: Operating systems may observe a #GP fault being serviced before higher priority Interrupts and Exceptions.

Workaround: None identified.

Status: For the steppings affected, see the *Summary of Tables of Changes*.

X33. A Write to an APIC Register Sometimes May Appear to Have Not Occurred

Problem: With respect to the retirement of instructions, stores to the uncacheable memory-based APIC register space are handled in a non-synchronized way. For example if an instruction that masks the interrupt flag, e.g. CLI, is executed soon after an uncacheable write to the Task Priority Register (TPR) that lowers the APIC priority, the interrupt masking operation may take effect before the actual priority has been lowered. This may cause interrupts whose priority is lower than the initial TPR, but higher than the final TPR, to not be serviced until the interrupt enabled flag is finally set, i.e. by STI instruction. Interrupts will remain pending and are not lost.

Implication: In this example the processor may allow interrupts to be accepted but may delay their service.

Workaround: This non-synchronization can be avoided by issuing an APIC register read after the APIC register write. This will force the store to the APIC register before any subsequent instructions are executed. No commercial operating system is known to be impacted by this erratum.

Status: For the steppings affected, see the *Summary of Tables of Changes*.



X34. The Processor May Report a #TS Instead of a #GP Fault

Problem: A jump to a busy TSS (Task-State Segment) may cause a #TS (invalid TSS exception) instead of a #GP fault (general protection exception).

Implication: Operation systems that access a busy TSS may get invalid TSS fault instead of a #GP fault. Intel has not observed this erratum with any commercially available software.

Workaround: None identified.

Status: For the steppings affected, see the *Summary of Tables of Changes*.

X35. BTS Message May Be Lost When the STPCLK# Signal Is Active

Problem: STPCLK# is asserted to enable the processor to enter a low-power state (C2, C3, etc.). Under some circumstances, when STPCLK# becomes active, a pending BTS (Branch Trace Store) message may be lost and not written to the Debug Store area.

Implication: BTS messages may be lost in the presence of STPCLK# assertions.

Workaround: None identified.

Status: For the steppings affected, see the *Summary of Tables of Changes*.

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Specification Changes

X1. AGTL+ Buffer on Resistance (R_{ON}) Specification Correction

The AGTL+ Buffer On Resistance (R_{ON}) specification has been corrected for *Intel Pentium M processor with 2-MB L2 cache and 533-MHz Front Side Bus. Intel® Pentium® M Processor with 2-MB L2 Cache and 533 MHz Front Side Bus Electrical, Mechanical, and Thermal Specification (EMTS) Revision 2.1 Table 3-7 AGTL+ Signal Group DC Specifications* shows R_{ON} specification as:

| Symbol | Parameter | Min | Typ | Max | Unit |
|----------|----------------------|-----|-----|-----|----------|
| R_{ON} | Buffer On Resistance | 22 | 25 | 28 | Ω |

Should state:

| Symbol | Parameter | Min | Typ | Max | Unit |
|----------|----------------------|------|------|------|----------|
| R_{ON} | Buffer On Resistance | 17.7 | 24.7 | 32.9 | Ω |

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Specification Clarifications

X1. Removed

See the Revision History for details.

X2. Thermal Diode Offset Spec Clarification

The following text has been added to Intel® Pentium® M Processor on 90-nm Process with 2-MB L2 Cache and Intel® Pentium® M Processor on 90-nm Process with 2-MB L2 Cache and 533 MHz Front Side Bus datasheets chapter 5, section 5.1.2, Thermal Diode Offset:

The thermal diode offset model specific register, THERM_DIODE_OFFSET, is located at offset 03Fh accessed as a QWord. Bits 7:0 contain the thermal diode offset value in 0.5 °C resolution. This value should be subtracted from the diode measurement after the thermal diode ideality adjustments are made. Values from bits 7:0 of the MSR are interpreted as follows:

'00000000' = 0 °C
 '00000001' = +0.5 °C
 '00000010' = +1 °C
 '01111111' = +63.5 °C
 '11111111' = -0.5 °C
 '11111110' = -1 °C
 '10000000' = -64 °C

Appended to footnote of Table 5-7, *Thermal Diode Specification*:

Offset value is programmed in processor Model Specific Register 03Fh, "THERM_DIODE_OFFSET"

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Documentation Changes

There are no Documentation Changes in this Specification Update revision.

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